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(54) Title of the Invention: Reflective Mirror

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Specification

1. Title of the Invention

Reflective Mirror

2. Claims

(1) A reflective mirror, wherein an intermediate layer consisting of a metal oxide is disposed on a base, a light-reflecting layer is laminated thereupon, and a protective layer is laminated on top of the light-reflecting layer if necessary.

(2) The reflective mirror described in claim (1), wherein the metal oxide used is an oxide of a metal selected from among chromium, titanium, tungsten, tin, indium and aluminum.

(3) The reflective mirror described in claim (1), wherein the light-reflecting layer is a nitride of aluminum, gold, silver, copper or titanium.

(4) A reflective mirror, wherein an intermediate layer consisting of a metal nitride is disposed on a base, a light-reflecting layer is laminated thereupon, and a protective layer is laminated on top of the light-reflecting layer if necessary.

(5) The reflective mirror described in claim (4), wherein the metal nitride used is a nitride of a metal selected from among chromium, titanium and tungsten.

(6) The reflective mirror described in claim (4) or claim (5), wherein the light-reflecting layer is a nitride of aluminum, gold, silver, copper or titanium.

3. Detailed Description of the Invention

[Industrial Field of Application]

The present invention relates to a reflective mirror that reflects all light.

The present invention relates more specifically to an easy-to-manufacture, high productivity reflective mirror with superior weather resistance in which the light-reflecting film is firmly secured to the base.

[Background of the Invention]

In general, reflective mirrors use a highly reflective metal such as silver, copper, gold or aluminum in the reflective layer.

When a metal reflective layer such as copper (Cu) is applied to a transparent base, an intermediate layer of chromium, tungsten, nickel or titanium that adheres well to both copper and the base can be applied between the copper and the base.

However, if the intermediate layer is too thick, the reflectivity of the metal layer on top may deteriorate. Therefore, the intermediate layer has to be kept thin between 5 Å and 50 Å. Unfortunately, if the transparent base is a synthetic resin for a reflective layer of copper, the metal layer may not adhere very well at this thickness.

These reflective mirrors also experience problems such as poor weather resistance because of film cracking.

In order to improve the adhesiveness of metal film to a synthetic resin base, layers of SiO_2, Cr and Al can be formed successively on top of the base, and then a minimum of six layers alternating between a low refractive material (SiO_2) and a high refractive material (TiO_2, CeO_3, Ta_2O_3 or a mixture of ZrO_2 and TiO_2) can be formed on top before applying a surface layer (SiO_2) to complete the reflective mirror.

Because this reflective mirror has a two-layer structure, manufacturing costs are increased. Also, there are limits on film thickness when metal chromium is used and SiO_2 is used in the portions where the synthetic resin member comes into contact with the metal film. If the synthetic resin is a polycarbonate, the film does not adhere sufficiently and some of the film can be peeled off by adhesive tape.

[Purpose of the Invention]

The purpose of the present invention is to provide an easy-to-manufacture, high productivity reflective mirror with superior weather resistance in which the light-reflecting film is firmly secured to the base.

[Constitution of the Invention]

In order to achieve this purpose, the present invention is a reflective mirror, wherein an intermediate layer consisting of a metal oxide is disposed on a base, a light-reflecting layer is laminated thereupon, and a protective layer is laminated on top of the light-reflecting layer if necessary.

The base used in the reflective mirror of the present invention can be an inorganic material such as a glass, ceramic or metal, or an organic high polymer material such as polystyrene, polymethylmethacrylate, polycarbonate or a copolymer of acrylonitrile and styrene. High precision components can be obtained using a molding method such as casting or injection molding.

A reflective mirror of the present invention with this type of base can be used as the 45° mirror in the laser optics of a laser printer, as a rearview mirror in an automobile, or as a backlighting mirror for a liquid crystal display.

The intermediate layer in a reflective mirror of the present invention can be an oxide of a metal such as chromium, titanium, tungsten, tin, indium or aluminum. Examples include chromium oxide, titanium oxide, tungsten oxide, tin oxide, indium oxide and aluminum oxide. Ideal oxides are chromium oxide and tin oxide.

Instead of a metal oxide, the intermediate layer in a reflective mirror of the present invention can be a nitride of a metal such as chromium, titanium or tungsten. Examples include chromium nitride, titanium nitride and tungsten nitride.

Because the intermediate layer of the present invention can be thicker than the prior art without causing problems, the acceptable range is wider than the prior art.

The thickness range for the intermediate layer of the present invention is generally between 50 Å and 2000 Å, and ideally between 100 Å and 1000 Å.

In a reflective mirror of the present invention, the light-reflecting layer formed on top of the intermediate layer can be a metal such as aluminum, gold, silver or copper, or a metal compound such as titanium nitride. The thickness of the light-reflecting layer is generally between 50 Å and 3000 Å, and ideally between 700 Å and 2000 Å.

In the present invention, a protective layer can be formed on top of the light-reflecting layer if necessary. To improve the reflecting effect, the layer should be silicon oxide (SiO_x, $1 \leq x \leq 2$) with the optical film thickness (nd) set to 1/2 of the reflected light wavelength (λ).

In the present invention, the protective film can be alternating layers of low refractivity (L layer) and high refractivity (H layer). The film should consist of at least six laminated layers. Ideally, the optical film thickness (nd) of the layers should be set to 1/2 of the reflected light wavelength (λ).

Here, the L layers should be SiO_2 or MgF_2, and the H layers should be TiO_2, CeO_2, Ta_2O_3 or a mixture of ZrO_2 and TiO_3.

[Effect of the Invention]

The following is an explanation of the effect of the present invention. In a reflective mirror of the prior art, in which a titanium (Ti) layer or a chromium (Cr) layer is formed as the intermediate layer on top of a clear base material such as glass and a copper (Cu) layer (thickness: 2000 Å) is formed on top of this as the light-reflecting layer, an increase in the thickness of the intermediate layer causes a decrease in reflectivity as described above.

Using the relationships established in FIG 1 and Table 1, FIG 1 shows the reflectivity of a semiconductor laser beam (wavelength: 1.3 μm) at an incoming angle of 45° off of a reflective mirror of the prior art, in which the intermediate layer is Cr and the light-reflecting layer is Cu (thickness: 2000 Å). The horizontal axis of the graph indicates the thickness of the Cr intermediate layer (Å) and the vertical axis indicates the reflectivity (%). Table 1 shows the reflectivity of light from the reflective mirror when the thickness of the Cr intermediate layer is 10 Å and 100 Å.

Table 1 (Reflective Mirror of the Prior Art)

Thickness of Cr Intermediate Layer (Å)	Reflectivity (%)	
	P Polarization	S Polarization
10	97	98
100	72	88

As seen in Table 1, an increase in the thickness of the Cr intermediate layer leads to a significant decrease in reflectivity in the case of both P polarization and S polarization.

If the base of this reflective mirror is polycarbonate, the film adheres inadequately when the thickness of the Cr intermediate layer is 10 Å. In a peeling test in which adhesive tape is applied and removed, some of the film peels off. When the thickness is 100 Å, the film adheres adequately but the reflectivity of the reflective mirror declines.

The tendency was the same when a laser beam with a wavelength of 780 nm was used.

In contrast, FIG 2 and Table 2 show the reflectivity of a semiconductor laser beam (wavelength: 780 nm) at an incoming angle of 45° off of a reflective mirror of the present invention, in which the intermediate layer is chromium nitride (CrN) and the light-reflecting layer is an aluminum (Al) layer with a thickness between 1000 Å and 2000 Å.

Table 2 (Reflective Mirror of the Present Invention)

Thickness of CrN Intermediate Layer (Å)	Reflectivity (%)	
	P Polarization	S Polarization
10	88	89
100	87	88
1000	86	87
2000	84	86

A comparison of the results in Table 1 and Table 2 show that the reflectivity of the reflective mirror of the present invention declines much less than Table 1 (the prior art) even when the thickness of the intermediate layer is increased.

Therefore, the acceptable range of thickness for the intermediate layer of the present invention is much broader than the prior art.

In other words, the present invention improves the adhesion of the light-reflecting layer to the base without causing a decline in the reflectivity of the reflective mirror and also improves the weather resistance of the reflective mirror.

Table 3 shows the relationship between the thickness of the CrN intermediate layer and the amount of peeling in the adhesive tape test described above in a reflective mirror of the present invention in which polycarbonate is used as the base material.

Table 3 (Reflective Mirror of the Present Invention)

Thickness of CrN Intermediate Layer (Å)	0	5	20	50	100	500	1000	2000
Layer Peeling Using Adhesive Tape	x	x	x	O	O	O	O	O

x ... Peeling O ... No Peeling

In these reflective mirrors, the improvement in reflectivity is 85% or more. As a result, the thickness of the CrN intermediate layer in a reflective mirror of the present invention can be selected within the range of 50 Å to 1500 Å in consideration of the amount of tape peeling that occurred in Table 3.

In the preceding explanation of the effect of the present invention, the intermediate layer was chromium nitride (CrN). However, other metal nitride and metal oxides can also be used as the intermediate layer. When the same tests as those performed on chromium nitride (CrN) were conducted to determine the optimum thickness for these nitrides and oxides, the results shown in Table 4 were obtained.

Table 4 (Reflective Mirror of the Present Invention)

Intermediate Layer	Optimum Thickness (Å)
Titanium Nitride	40-2000
Tungsten Nitride	50-1600
Chromium Oxide	30-1500
Titanium Oxide	20-1800
Tungsten Oxide	50-1600

Tin Oxide	30-2000
Indium Oxide	50-2000
Aluminum Oxide	20-1000

In the present invention, when a metal oxide or metal nitride is formed as the intermediate layer on top of a base, a light-reflecting layer is formed on top of this, and a protective layer is formed on top of the light-reflecting layer of silicon oxide (SiO_x, $1 \leq x \leq 2$) with the optical film thickness (nd) set to 1/2 of the reflected light wavelength (λ) such as 780 nm, the protective layer increases the reflectivity 3 to 5%.

The reflectivity of a reflective mirror of the present invention can also be increased if a protective film is formed on top of the light-reflecting layer that consists of alternating layers of low refractivity (L layers) made of a low refractivity materials (SiO_2 or MgF_2) and layers of high refractivity (H layers) made of a high refractivity materials (TiO_2, CeO_2, Ta_2O_3 or a mixture of ZrO_2 and TiO_3).

Therefore, the protective layer on top of the light-reflecting layer in the present invention can be altered if necessary.

[Working Examples]

The following is a more detailed explanation of the present invention with reference to working examples. The present invention is by no means limited to these working examples.

In these working examples, the intermediate layers, light-reflecting layers and protective layers are formed using the high-frequency ion plating method. However, other layer forming methods such as the sputtering method can be used in the present invention.

Working Example 1

A base was molded from polycarbonate, and a chromium nitride layer was deposited on top of the base using the high-frequency ion plating method, in which the chromium deposition source was heated using an electron beam. The following were the film-forming conditions.

High-Frequency Discharge Power	1 Kw (Reflected Wave 100 W) 13.56 MHz
Base Temperature	No Heat From Heater
Nitrogen Gas Pressure	3×10^{-6} Torr
Film Thickness	100 Å - 1000 Å

A light-reflecting layer (Al layer) and protective layer (SiO_2 layer) were then formed successively on top of the chromium nitride intermediate layer to complete a reflective mirror of the present invention.

Reflective Layer (Al Layer) Formation Conditions

Deposition Source	Al Heated and Deposited Using Electron Gun
Degree of Vacuum	$1\text{-}5 \times 10^{-6}$ Torr
Film Thickness	100 Å - 1000 Å

Protective Layer (SiO_2 Layer) Formation Conditions

Deposition Source	SiO_2 Heated and Deposited Using Electron Gun
Degree of Vacuum	2×10^{-6} Torr
Film Thickness	2500 Å

The reflectivity of a semiconductor laser beam (wavelength: 7800 Å) at an incoming angle of 45° off of the reflective mirror was 88%-86% (P polarization) and 89%-87% (S polarization).

No peeling was observed after performing an adhesive tape peeling test on the reflective mirror. Consequently, film adhesion was good.

No peeling was observed even after the reflective mirror was exposed for 24 hours to environmental conditions of 60°C and 90% r.h (weather resistance test).

Working Example 2

A base was molded from polymethylmethacrylate, a tin oxide layer was deposited on top of the base using the high-frequency ion plating method, in which the tin deposition source was heated using an electron beam. The following were the film-forming conditions.

High-Frequency Discharge Power	1 Kw (Reflected Wave 100 W)
Base Temperature	No Heat From Heater 13.56 MHz
Nitrogen Gas Pressure	8×10^{-6} Torr
Film Thickness	50 Å - 1000 Å

A light-reflecting layer (Al layer) and protective layer (SiO_2 layer) were then formed successively on top of the tin oxide intermediate layer in the same manner as the first working example to complete a reflective mirror of the present invention. The reflectivity of a semiconductor laser beam (wavelength: 7800 Å) at an incoming angle of 45° off of the reflective mirror was 87%-85% (P polarization) and 88%-85% (S polarization).

When the peeling test and the weather resistance test in the first working example were performed under the same conditions as the first working example, the results were as good as those in the first working example.

Working Example 3

A base was molded from polycarbonate, and a titanium nitride layer was deposited on top of the base using the high-frequency ion plating method, in which the titanium deposition source was heated using an electron beam. The following were the film-forming conditions.

High-Frequency Discharge Power	1 Kw (Reflective Wave 100 W) 13.56 MHz
Base Temperature	No Heat From Heater
Nitrogen Gas Pressure	3×10^{-6} Torr
Film Thickness	100 Å - 1000 Å

Next, a light-reflecting layer (Al layer) and protective layer (SiO_2 layer) were formed successively on top of the titanium nitride intermediate layer in the same manner as the first working example to complete a reflective mirror of the present invention.

The reflectivity of a semiconductor laser beam at a wavelength of 7800 Å and an incoming angle of 45° off of the reflective mirror was 89%-85% (P polarization) and 89%-86% (S polarization).

When the peeling test and the weather resistance test in the first working example were performed under the same conditions as the first working example, the results were as good as those in the first working example.

4. Brief Explanation of the Drawings

FIG 1 shows the relationship between reflectivity and Cr intermediate layer thickness in a reflective mirror of the prior art. The horizontal axis of the graph indicates the thickness (Å) of the chromium intermediate layer (Cr layer) and the vertical axis indicates the reflectivity (%) of the reflective mirror.

FIG 2 shows the relationship between reflectivity and the intermediate layer thickness in a reflective mirror of the present invention. The horizontal axis of the graph indicates the thickness (Å) of the intermediate layer and the vertical axis indicates the reflectivity (%) of the reflective mirror.

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FIG 1

S Polarization

P Polarization

FIG 2

S Polarization

P Polarization